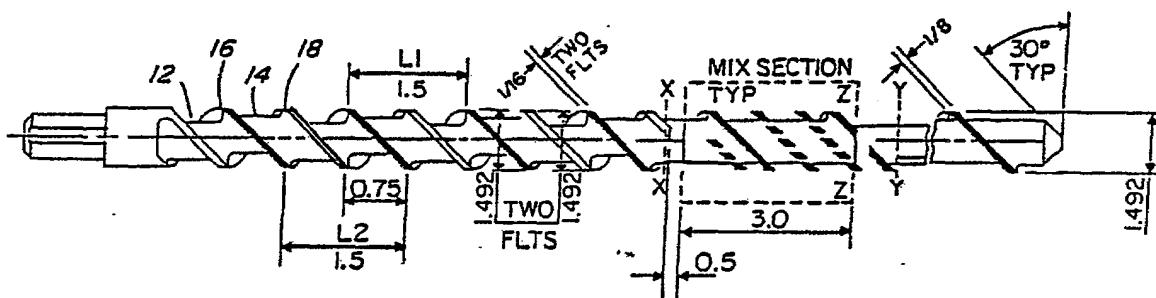




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(21) International Application Number: PCT/US87/02062 (22) International Filing Date: 19 August 1987 (19.08.87) (31) Priority Application Number: 897,987 (32) Priority Date: 19 August 1986 (19.08.86) (33) Priority Country: US (71)(72) Applicants and Inventors: ALZNER, Bernard, G. [US/US]; 41 East North Avenue, Lake Forest, IL 60045 (US). CSONGOR, Desider, G. [US/US]; 19 Bennett Street, Manchester, MA 01944 (US). (74) Agents: SMITH, James, M. et al.; Hamilton, Brook, Smith & Reynolds, Two Militia Drive, Lexington, MA 02173 (US).		(81) Designated States: AT (European patent), BE (European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), HU, IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent), SU. Published <i>With international search report.</i>

(54) Title: PLASTICISING EXTRUDER SCREW**(57) Abstract**

A plasticating extruder screw effectively broadens the useful operating range of the single screw extruder by incorporating two or more screw configurations into a single screw. This is accomplished with two or more parallel channels (12, 14) in which each channel is designed to a different set of materials and performance requirements reflecting the range of the materials to be processed. The extrusion screw in fact represents two or more screws in a single screw in which each performs its function independently of the other. Thus, each channel in this screw differs from the others in critical design parameters such as compression ratio, length and depth of its feed, transition and metering zones. This multiconfigurational design feature may occupy part or the entire length of the extruder as dictated by the specific characteristics of the materials to be processed. A mixing and stabilization zone placed at or near the entrance of the metering zone of the screw provides for melt flow interaction and equilibration between channels. The screw terminates in a metering zone comprised of one or more channels designed in accordance with known principles.

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Plasticising extruder screw.

Background of the Invention

Extrusion screws featuring two or more parallel channels are among the first types of screws used in the trade. These screws, in which all channels within a given screw are of identical configuration, usually of relatively low compression ratio as measured by the ratio of feed to meter channel depth. These types of screws were replaced by the single channel screw which was found to be more effective than the multichannel screw described above. Increasing emphasis was placed on optimization of the single channel screw with the aid of computer programs as these became available. While these developments produced considerable performance improvements they, nevertheless, failed to cope with the variability in materials and process encountered in the trade.

The last decade witnessed the appearance of several unique types of extrusion screws intended to overcome the variability problems described. The most noteworthy of these developments is the barrier screw. While many variations of the basic barrier concept were produced, they all feature a nonparallel minor flight in the transition, i.e. melting, zone whose purpose is to separate the solid from the melt where these two phases coexist. It accomplishes this by allowing the melt to pass over the minor flight which is of a lesser height than the major flight while containing the solid pellets in the original channel. The minor flight is faced out at the calculated point of complete conversion

-2-

of solid to melt. This condition is only realized when design parameters are satisfied which is rarely the case in practice.

Summary of the Invention

- 05 In accordance with the present invention, an extruder plasticizing screw comprises two or more parallel channels defined by parallel flights. Each channel is of unique configuration relative to width, depth and/or length of its functional feed transition and/or metering zones. Each channel receives the supply of material, but each is designed to a different set of material characteristics in order to extend the range of materials which can be handled by the screw. The output of the two channels is mixed in a mixer which may be incorporated onto the screw. The flights defining the channels provide minimal clearance to minimize interference between the channels prior to mixing.
- 10 15 20 25 Preferably, the melt emerging from the channels is pooled in a single channel. The single channel has a cross-sectional area adjacent to the exit end of the multichanneled section at least 20 percent greater than the cross-sectional area of the discharge end of the multichanneled section.

Brief Description of the Drawings

- Figure 1 illustrates the performance characteristics of a screw embodying the present invention and of a commercially available barrier mixer type of screw.
- 30

Figure 2A is a side view of a screw embodying the present invention, Figure 2B is the root diameter profile of the screw, and Figure 2C sets forth additional design parameters of the screw.

5 Preferred Embodiment

The screw is the heart of any extruder. It performs all of the essential functions of the extruder which include solids conveying and compacting, melting, mixing and homogenization of the melt, and pumping which it must do at a consistent rate. Failure in any one of these functions will adversely affect the others. Optimum performance of these functions is achieved through the development of a screw configuration dictated by specific materials and performance characteristics. The polymeric material processed by such extruders is usually supplied in pellet, powder or granular form. It is well known in the art that these materials differ widely in their processing characteristics. In fact, lot to lot variations within a specific type or brand of polymer from a single source is not uncommon. The use of scrap necessitated by economic considerations further aggregates variability in the feed stock as dissimilar particles exhibit different processing characteristics. This can cause destabilization in the feed and melting zones which usually remain uncorrected in the metering zone. It is a common practice among convertors to resort to the use of several screws to effectively cope with such material variability.

It is the objective of this invention to provide a multiconfigurational screw in a single

-4-

screw which has a broader useful operating range than is obtainable with a single configuration. This is accomplished by incorporating two or more parallel channels in critical portions of the screw

05 in which each channel is optimized to a different set of materials and performance characteristics reflecting the variability encountered in the material to be processed. The flights separating the channels are designed to a minimum clearance so

10 that each channel functions with the minimum interference from adjacent channels. Each channel thus formed differs from the other in important design parameters such as compression ratio, length and depth of its zones particularly its feed and

15 transition zones. Each channel is designed for optimum performance to different materials and performance requirements dictated by variations encountered in the material and process. Problems developed in one channel will be compensated for in

20 the other with the configuration better matched to the material processed. A mixing and flow stabilization zone placed in the metering zone near the end of the multi-configurational section of the screw insures equilibration and stabilization of the

25 melt quality and flow.

The multiconfigurational screw of the invention was found to exhibit a broader operating range than is obtained with single channel screws and other types known in the trade. Performance

30 characteristics of such a screw are depicted for a number of difficult to process polymers in Figure 1. A similar performance study performed on a screw enjoying wide customer acceptance in the trade

-5-

is depicted in Figure 1. While the commercial screw of Figure 1 exhibits a decline in its pumping efficiency with increasing output, i.e. RPM as measured by its displacement in pounds per
05 revolution, the screw of this invention exhibited constant and, in some cases, improved pumping efficiency with increasing RPM. This result is particularly surprising in the case of the high density polyethylene, both of which are known for
10 their poor processing characteristics. The other surprising fact revealed in this study is the wide range of dissimilar materials so effectively processed in the screw of this invention.

Another less obvious benefit attributable to
15 high pumping efficiency is the reduction in shear energy per pound of material processed which should be kept to a minimum with most polymers.

Still another advantage observed with the type of screw described herein is in the dimensional
20 consistency of the extrudate as measured by the mean and standard deviation data shown below in comparison to a standard. Accordingly, the screw of subject invention exhibits less fluctuations and greater tolerance for materials related variables
25 than the standard used in these tests. The standard is a barrier type screw which enjoys considerable popularity in the trade.

-6-

Variations in film thickness
at 60 screw RPM observed with the commercial
and multiconfigurational screws

	<u>MATERIAL</u>	<u>MI</u>	<u>COM. (STD)</u>	<u>SCREW</u>	<u>MULTICONFIGURATIONAL</u>	
			<u>GA(mils)</u>	<u>STD.D</u>	<u>GA(mils)</u>	<u>STD.D</u>
05						
	HDPE 'A'	0.4	4.1	0.7	4.2	0.3
	HDPE 'B'	0.6	4.8	0.5	4.7	0.2
	LLDPE	1.5	4.5	0.9	4.6	0.6
	Mod'd'A'	0.7	4.3	0.4	4.4	0.4

10 The essential design features of the extrusion
screw described above are detailed in Figures 2A-2C.
Accordingly, said screw contains two or more
parallel channels 12 and 14 separated by parallel
flights 16 and 18 in the feed zone and at least in
15 50% of the transition zone. It is essential that
each channel in this section of the screw is
designed to a different set of design parameters
defining the range of variability encountered with
the materials to be processed. In this example the
20 configurational differences were developed for
optimum solid conveying and melting of polymeric
material differing in bulk density as is the case
with the inclusion of reclaimed scrap in virgin
resin at varying concentrations. The resulting
25 channels exhibit significant configurational
differences in the feed, transition and metering
zones as illustrated in Figure 2A-2C.

In particular, it can be noted from the root
diameter profile of Figure 2B and the number of

-7-

turns indicated in Figure 2C that each zone is of a different length for each channel. In particular, the first channel has a feed zone of 4.5 inches and three turns, a transition zone of 13.5 inches and
05 nine turns and a meter zone of 3 inches and two turns. The second channel on the other hand has a feed zone of twice the length, 9 inches and six turns, a transition zone of 10.5 inches and seven turns and a meter zone of only 1.5 inches and one
10 turn. The lengths L1 and L2 between common points on each flight remain constant for both flights at 1.5 inches. The depths of the channels vary differently as illustrated by the broken and solid lines of Figure 2B and the dimensions set forth in
15 Figure 2C. The first channel has a compression ratio at XX of 2.8, and the second channel has a compression ratio of 2.0.

An important element in this screw consists of a mixing and stabilization zone placed at or near
20 the end of the multichanneled section. Any mixing configuration known in the art may perform adequately. In its simplest form, this zone may be comprised of a single channel having a melt volume cross-sectional area, YY, at least 20 percent
25 greater than the combined cross-sectional areas of the preceding multi-channelled section, XX. Melt mixing and stabilization is further enhanced by a complete interruption of the flights for a short interval, i.e. .25 to approximately 1 inch, at the
30 entrance of the decompression point, YY, preferably between the mixing and the decompression sections, i.e. at ZZ on the drawing. The sequence of mixers, interrupted flight portion and decompression channel

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comprising an effective melt mixing and flow
stabilization zone. The screw is terminated at the
discharge end by a single or multichanneled metering
section designed in accordance to know principles of
5 extrusion.

CLAIMS

1. An extruder plasticating screw comprised of two or more parallel channels defined by parallel flights in which each channel is of unique configuration.
5
2. An extrusion screw as claimed in Claim 1 in which the feed zone and at least 50 percent of the transition or melting zone is comprised of two or more parallel channels.
- 10 3. An extrusion screw as claimed in Claim 1 in which each channel is designed to a different set of materials characteristics.
4. An extrusion screw as claimed in Claim 1 in which each channel is designed to a different set of process requirements.
15
5. An extrusion screw as claimed in Claim 1 in which each channel differs from the other in at least one of several dimensional characteristics including width, depth or length of its functional zones which include the feed, transition or melting, and metering zones.
20
6. An extrusion screw as claimed in Claim 1 in which the melt emerging from the various channels is 'pooled' in a single channel.

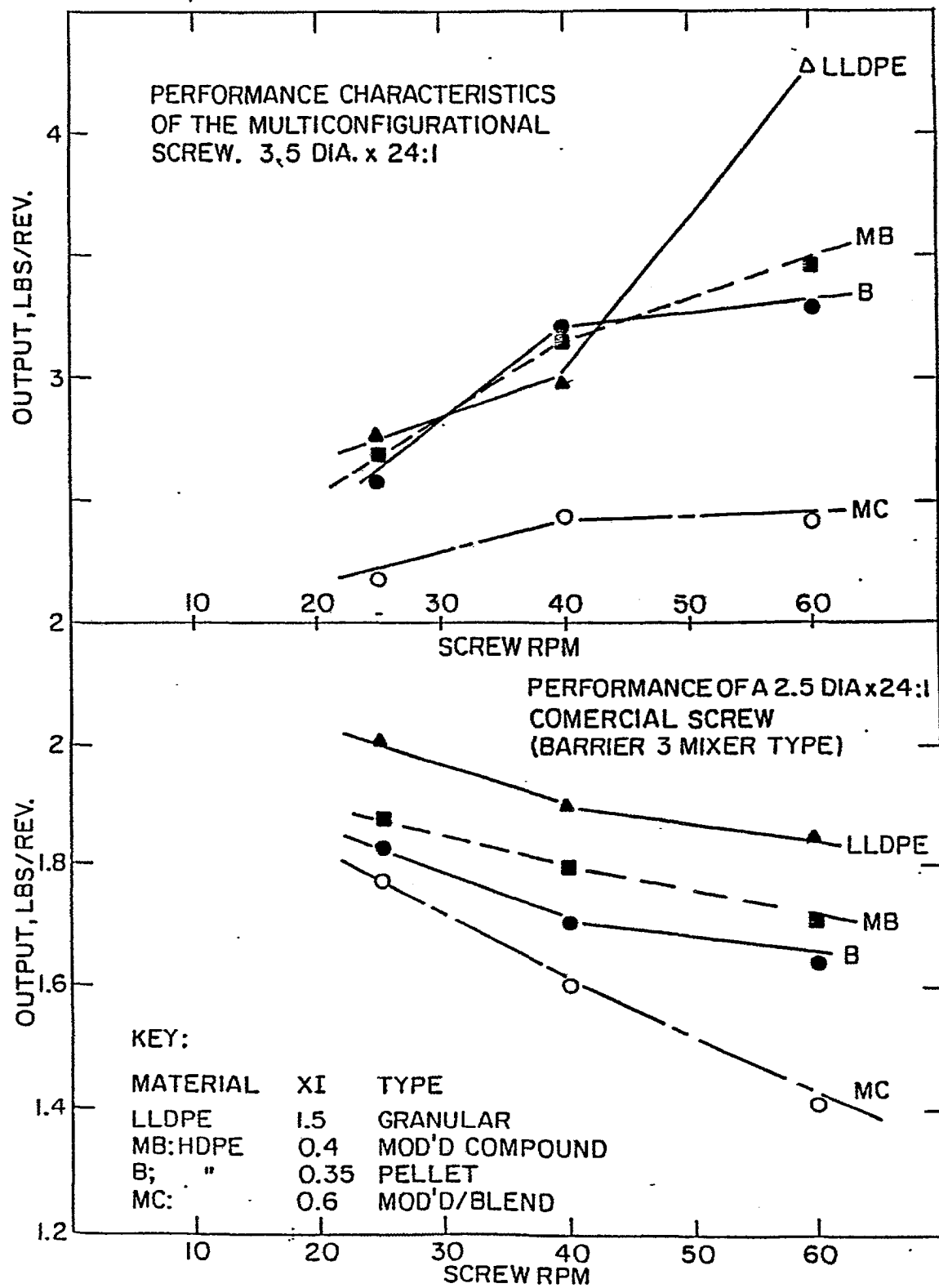
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7. An extrusion screw as claimed in Claim 1 in which the melt emerging from the various channels is combined and mixed in a common mixing section.
- 5 8. A screw as claimed in Claim 6 in which the single channel has a cross sectional area adjacent to the exit end of the multichannelled section at least 20 percent greater than the cross sectional area of the discharge end of
10 the multichannelled zone or section.
9. A screw as claimed in Claim 8 which has a melt mixing and stabilizing zone comprised of a mixing section as described in which the melt emerging from the various channels is combined
15 and mixed.
10. An extrusion screw as claimed in Claim 9 containing a melt mixing and stabilizing zone comprised of a mixing section followed by a decompression channel in which the channel
20 flight(s) are completely interrupted for a short interval between the mixing and decompression channel, said interval being about 0.25- to 1 inch in length.
11. An extrusion screw as claimed in Claim 1 which
25 terminates at the discharge end in a single or multichannel metering section.

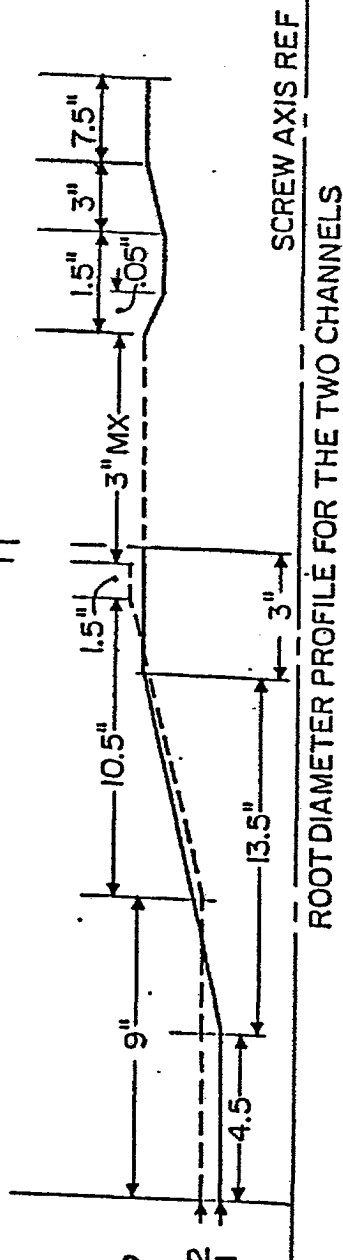
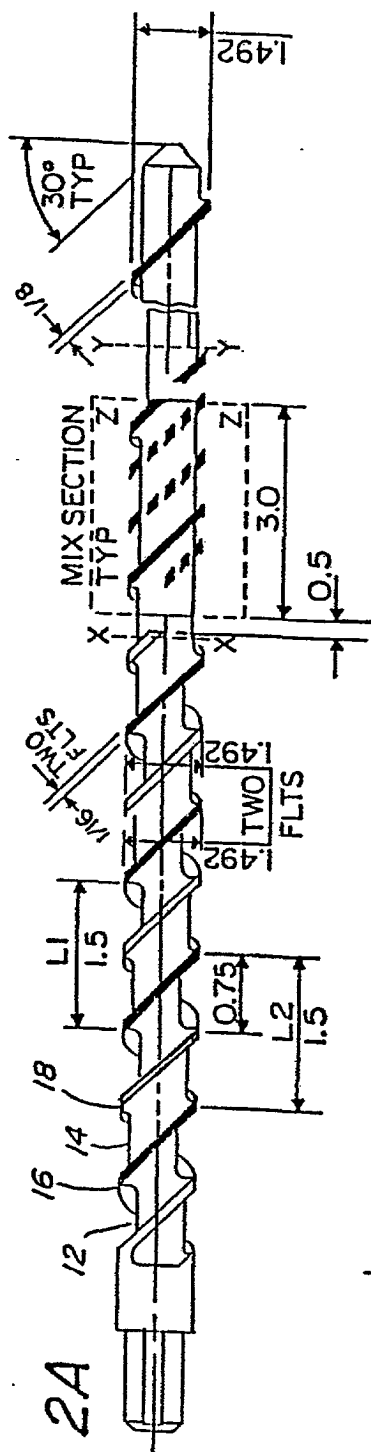
-11-

12. An extrusion screw as claimed in Claim 1
wherein each of the two or more parallel
channels includes a feed, transition and meter
zone, the lengths of the zones differing
5 between channels.
13. An extrusion screw as claimed in Claim 1
wherein the flights provide minimal clearance
to minimize interference between channels.
14. An extruder incorporating the screw of Claim 1
10 further comprising a single feed to both
channels and means for mixing the outputs of
the two channels.

FIG. 1



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DESIGN SPECIFICATION
1.5 x 24:1 SCREW
COMPRESS RATIO AT XX: CHANNEL 1: 2.8; CHANNEL 2: 2.0

ZONE	FEED	TRANSITION	IST METER	MIXING	FEED	FINAL METER	
						TRANS	PUMP
CHAN:I L1	1.5	1.5	1.5	-	1.5	1.5	1.5
-NO. TURNS	3	9	2	2	1	2	5
-DEPTH	0.45	-	0.160	-	0.220	-	0.150
CHAN:II: L2	1.5	1.5	1.5	-	-	-	-
-NO TURNS	6	7	1	-	-	-	-
-DEPTH	0.30	-	0.145	-	-	-	-

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 87/02062

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶ According to International Patent Classification (IPC) or to both National Classification and IPC IPC ⁴ : B 29 C 47/62; B 29 C 47/64		
II. FIELDS SEARCHED <div style="text-align: center; border-top: 1px solid black; border-bottom: 1px solid black; margin: 5px 0;">Minimum Documentation Searched ⁷</div> <div style="display: flex; justify-content: space-between;"> Classification System : Classification Symbols </div> <div style="margin-top: 10px;"> IPC⁴ : B 29 C </div> <div style="text-align: center; border-top: 1px solid black; border-bottom: 1px solid black; margin-top: 10px;"> Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸ </div>		
III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹		
Category ¹⁰ :	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
X	DE, A, 1909009 (F. KRUPP GmbH) 10 September 1970 see claims 1-4; figures 1-3	1-6,11-14 7-10
Y	--	
A	Patent Abstracts of Japan, volume 7, no. 12 (M-186)(1157), 19 January 1983, & JP, A, 57169337 (NIPPON SEIKOSHO K.K.) 19 October 1982	1-6,11-14
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A	DE, A, 3501851 (BARMAG BARMER MASCHINEN- FABRIK AG) 14 August 1985 see abstract; claims; figure 1	1-5,12,13
A	US, A, 3912241 (U. OESTREICH) 14 October 1975	
<div style="display: flex; justify-content: space-between; font-size: small;"> <div style="width: 45%;"> <p>¹⁰ Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&" document member of the same patent family</p> </div> </div>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search		Date of Mailing of this International Search Report
20th November 1987		10 DEC 1987
International Searching Authority		Signature of Authorized Officer
EUROPEAN PATENT OFFICE		

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category*	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
	see claims 1-3; figure 1	1,2,6,8, 11,13,14
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A	GB, A, 1590381 (J.K. NORMANTON et al.) 3 June 1981 see page 2, lines 33-43; figure 1	1-5,12,14
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A	US, A, 4054403 (R.L. HORNBECK et al.) 18 October 1977 see column 1, lines 24-33; figure 1	1-5,12,13
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A	GB, A, 2028218 (MANNESMANN DEMAG AG) 5 March 1980 see page 1, lines 110-113; figure 1	1-5,12,13
	--	
A	US, A, 3713627 (M. SKOBEL) 30 January 1973 see claims; figures 1,6	1-5,12,13
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A	DE, A, 3311176 (AEG-TELEFUNKEN KABELWERKE AG) 4 October 1984 see claims; figure 1	1-5,12,13
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A	EP, A, 0034505 (W.H. WILLERT INC.) 26 August 1981 see abstract; figures 1-5	1-5

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO.

PCT/US 87/02062 (SA 18595)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 25/11/87

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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DE-A- 3311176	04/10/84	None	
EP-A- 0034505	26/08/81	JP-A- 56135045 US-A- 4330214	22/10/81 18/05/82

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